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ABSTRACT

Research data in neurosurgery, neuropsychology, and neurolinguistics indicate that the human brain is lateralized toward one of two methods of information processing, and that, in most humans, the language bias appears to be a left hemisphere function, while the visiospatial bias belongs to the right. Furthermore, the left hemisphere seems to perceive and process information in parts, while the right hemisphere perceives and processes information in wholes. These data have been used to investigate many facets of the teaching/learning process. Such studies have discovered that readers who process written material using a predominantly left hemisphere strategy of sequencing, without integrating the right hemisphere visualization strategies, may be able to read but not comprehend. Those readers who appear to have good visualization skills--a right hemisphere strategy--but lack the sequencing skills of the left, have great difficulty developing overall reading skills. The educational challenge, therefore, becomes one of teaching the whole child, to approach each hemisphere's processing strengths, to provide exercises that will allow for the integration of perceptual strategies in reading, and to produce holistic thinkers. (HOD)

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RECENT RESEARCH INTO THE HEMISPHERICITY OF THE HUMAN BRAIN AND THE IMPLICATIONS OF THOSE FINDINGS IN THE TEACHING OF READING

Emerson wrote that "One must be an inventor to read well. . . (that) there is creative reading as well as creative writing." Most of the research data in neurosurgery, neuropsychology, and neurolinguistics of the recent past indicates that if students are to be trained as readers--and not simply as word processors--they should be trained as creative readers, or readers who can use their brains to process the information imparted by printed words in a holistic fashion. Basic research into the mechanisms and functions of the human brain of the past twenty-five years has provided evidence of the nature of the perceptual bias of each hemisphere of the brain that may enable educators and text writers to provide more effective materials and strategies for the teaching of reading. With that foundation of data, educational researchers have examined processing strategies that appear to be inherent to each half, and the ways in which the two hemispheres appear to cooperate in the reading process. Based on both the basic research data and the findings of the educational researchers, theorists and educators have offered practical suggestions for those who teach, and for those who create the materials with which to teach.

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In an article in SCIENCE magazine in October, 1981, Michael Gazzaniga, professor of psychology in neurology at Cornell Medical Center, and former research assistant to Roger Sperry, wrote that Professor Sperry and his team at the California Institute of Technology "laid the groundwork for much of the present-day field of developmental neurobiology--the experiments of which probably consume about half of all (current) activities of neuroscientists" (Gazzaniga, 1981, 518). That perhaps half of the time spent in neurobiological research is spent on projects with their roots in Sperry's data, for which he won the 1981 Nobel prize, is indicative of the significance of this relatively new field of brain research.

Trained in the behavioristic model of brain function that had been popular since the experiments of Pavlov, Sperry is said by Gazzaniga, to have intuitively rejected the thesis of his mentor at the University of Chicago, Professor Paul Weiss, that in the mechanisms of the brain, "function precedes form." Much of Sperry's doctoral work had involved split brain studies with animals, and by the early 1950's, his papers on "The Neural Basis of the Conditioned Response," and "Neurology and the Mind-Brain Response," (Gazzaniga, 1981, 528) had made him a recognized leader in brain research.

When Sperry was invited to be the Hixon Professor of Psychobiology at Caltech, the patients of neurosurgeons, Joseph and Phillip Vogel, who had undergone commissurotomy were made available for him to study. Commissurotomy involves the

surgical splitting of a large group of nerve fibers, called the corpus collosum, that join the left and right hemispheres of the cerebrum, a technique for the treatment of epilepsy based on the animal studies Sperry had done at the University of Chicago.

It is a "pecularity of the human nervous system that each cerebral hemisphere receives information primarily from the opposite half of the body. . . ," according to Doreen Kimura of the Montreal Neurological Institute, in an article in SCIENTIFIC AMERICAN, March, 1973 (228, 70-79). Information is received along pathways of nerves directly connected to the sensory organs. The neural pathways cross at points that are physically lower in the brain than the corpus collosum. Therefore, information is received from the right sensory organs into the left hemisphere of the brain, and from the left sensory organs to the right hemisphere. Although neuroscientists had knownof the crossed state of the nervous system for more than a century, the "function of the corpus collosum. . . (that joined the two hemispheres of the upper cerebrum) was still an enigma in the early 1950's" (Sperry, SATURDAY REVIEW, 1975, 2, 23-30).

Research with animal commissurotomies and with humans born without a corpus collosum had indicated little, if any,behavorial or personality effect of that particular bundle of nerve fibers, or by its absence. With the human commissurotomy patients, Sperry began to investigate the role of the corpus collosum and its function in the brain.

Much was learned about the role of that organ, but far more was learned about the processing functions of the brain itself, an unanticipated event. Sperry's studies, according to Gazzaniga, helped to "elucidate the biological and psychological nature of (humans). . . helped to define and advance knowledge about the brain like no other scientist in the history of the world" (SCIENCE, 214, 518).

Using dichotic listening techniques, developed by Britain's Donald E. Broadbent, the scleral lens techniques invented by a research assistant, Dahlia Zaidel, and using tasks that called for either a verbal response or a choice response from an array of objects to visual stimulation (Gazzaniga, 1967, Kimura, 1973, and Gazzaniga, 1977), Sperry and his associates found that the corpus collosum was indeed of critical significance in allowing stimuli perceived by one hemisphere

to be transferred to the other hemisphere, and in allowing coordination of the perceptual strengths of each hemisphere. The corpus collosum was so vital to communication between the hemispheres that it was as if, when the pathway between them was no longer available, the brain became divided or split, with one realm of consciousness totally separated from the other. Extensive testing indicated that in commissurotomy patients, each hemisphere contained a conscious realm of experience that remained totally unaware of stimuli received by the opposite hemisphere (Gazzaniga, 1977).

The implications of these data in comprehending the functions of each part of the brain, and the brain as a whole in cognitive processing, was to become the subject of further research studies carried on by the members of the group of assistants trained by Sperry, a list of the names of which make up the entire battery of those involved in the contemporary study of brain function.

The notion of hemisphericity, or the lateralization of abilities, in normal human subjects, was a popular notion that grew out of the work of Sperry and his second generation of researchers. Hemisphericity is the notion that specific functions are indigenous to each hemisphere. Lateralization refers to the concept that each human has a dominant hemisphere that reacts a split second before the other, and thereby controls the cognitive strategy bias of the individual. Lateralization may be analagous to right or left handedness. Although most humans can use either hand for most functions, the normal person has a bias toward using one hand in preference to the other. Similar bias is thought to exist in the brain, with the perceptual strategies of one hemisphere or the other being dominant.

Because Sperry's subjects were able to use language in describing the stimuli presented to the left hemisphere, the notion that language as a function resided in the left half of the brain became an important concept in the theory of hemisphericity. Because those subjects had been unable to use words in their responses to stimuli presented to the right hemisphere

but had responded to pictures and choice arrays of objects, the early assumption was that the right half of the brain lacked language abilities, but could respond in a more primative fashion to visual stimuli (Galen, 20-29).

Using lateral eye movements, "handedness," and timed verbal response tests, several researchers working with normal, non-commissurized subjects concluded that in normal humans, lateralization was toward the left hemisphere, if a person were right-handed, and toward the right side of the brain if the person were left-handed. Because a majority of the subjects studied were right-handed, and because most subjects presented test evidence of having left hemisphere language abilities, lateralization toward the left hemisphere became the ideal of the 1970's. This was true to the extent that Stephen D. Krashen, professor of linguistics at UCLA, wrote in 1977 that "certain individuals never attain the adult level of cerebral specialization of functions" (Krashe, 119), noting that cultural depravation appeared to be a factor in this "failure," except for left-handers and women, in whom he failed to comprehend the reasons for failure to reach "adult" levels of specialization.

During this period of time, the left hemisphere was referred by many in the field as the "Major" hemisphere, and the right side as the"minor" (Nebes, 97). Professor Nebes of Duke writes in THE HUMAN BRAIN (Prentice-Hall, 1977, Wittrock, editor), that the left hemisphere "was the first found to possess a cognitive function unique to it... .(so) it seemed logical that the hemisphere

in which comprehension and production of language takes place should be more highly developed, and in control of the rest of the brain. . . the prevailing theory for many years was that. . . all higher mental functions were carried out in the left hemisphere" (Nebes, 98). It was assumed that because the left hemisphere appeared to control speech that it therefore controlled the production of language as well.

However, according to Sperry in his Nobel prize speech (SCIENCE, 1982), "early studies seemed to show that the disconnected right hemisphere was by no means either word-deaf. . . nor word blind." It was, according to lateralized testing for linguistic abilities, "largely mute and agraphic in the subjects tested. But it could comprehend at a moderately high level, words spoken aloud by the examiner and "could read printed words flashed to the left visual field. . ." It could tactually retrieve objects from a choice array, not only when the objects were directly named, but it seemed to understand complex spoken phrases and metaphors.

In the late 1970's further testing of the right hemisphere using commissurotomy patients also indicated that the "minor" hemisphere recognizes shapes, faces, visual images, and spatial arrangements. It displays "appropriate emotional reactions, has a sense of humor. . . a surprising knowledgeability in general. . . (and) even when mute, (is) capable of high level of cognitive functions" (Sperry, 1982, 224). These data were supported with later work with normal subjects. According to

Sperry, the hemispheres were not"Major" and"minor." The two sides of the brain simply possess two different and distinct strategies for processing the stimuli that either side receives, and the corpus collosum plays an important part in the utilization of both strategies.

Blood studies using radioactive isotopes injected into the bloodstream, pioneered by Neils Lassen and David Ingvar, indicated "a small but highly significant hemispheric difference of about 3% in blood flow" (Springer, 93-94), when subjects were engaged in verbal analogies tasks, and when they were engaged in picture completion tasks. Using a more advanced technique of mapping the cognitive activities of the brain, called PET, positron emission tomography, Martin Reivich at the University of Pennsylvania and Michael Phelps at UCLA, are investigating the location of metabolic activity in the brain during specific tasks. Their current subjects exhibit greater blood flow activity in the left hemisphere during oral language tasks, but the right hemisphere shows activity as well. When subjects were involved in spatial tasks, the right hemisphere showed greater activity, but the left hemisphere showed activity as well. Their data indicate that in normal persons, most activities involve some cooperation between the two hemispheres (Begley, et al., 40-47), the function of the corpus collosum.

Doreen Kimura at the Montreal Neurological Institute has produced data that indicate that in a small proportion of the

population appears to have language perceptual abilities in the reverse of the majority of subjects. Using the sodium amytal test developed by John A. Wada, she has studied a number of right-hemisphere-language-ability subjects, and has gained greater insights into the functions of the language processing capacities of the average person by comparison. Using a variety of established techniques, Kimura found that most normal or brain damaged patients, except those with right hemisphere language, reported words perceived through the right ear (left hemisphere processing) more accurately than the reverse. This superiority for the perception of speech held true for the perception of vowel-consonant syllables such as those that make up the phoneme systems of spoken languages. She also found that melodies were perceived more accurately through the left ear(right hemisphere processing), unless the melodies were hummed by a human voice, in which case, the right ear (left hemisphere) was more accurate. Her data would indicate that among the functions of the left hemisphere processing strengths is the specific ability to process the sounds created by the human articulatory system. That the left hemisphere seems highly attuned to the strategies of human communication, a theory that has been supported by her findings that point to a right visual field/left hemisphere superiority for both words and letters. Other tests indicated that deaf subjects process sign language faster and more accurately with the right hand (left hemisphere). The same was true of blind subjects using

Braille. She noted also that deaf subjects with stroke damage to the left hemisphere experienced problems with sign language analagous to speech problems common to patients with damage to similar areas of the brain.

A majority of studies in brain research have supported the findings of Sperry, and have further broadened the scope of knowledge about the inner workings of the brain. The main thrust of the data examined for this paper seem to indicate that the human brain appears to be lateralized toward one of the two methods of information processing, and that,in most humans, the language bias appears to be a left hemisphere function, while the visio-spatial bias belongs to the right. However, as more sophisticated techniques have been developed, it appears that the cooperation between the two hemispheres in the processing of stimuli in the normal brain is far greater than the initial work with commissurotomy patients indicated.

Two broad generalizations are supported with a wide range of data, that the "left hemisphere appears to specialize in data whose significance is built across time. . . while the right is specialized in data whose significance is built across space. . . (Hunter,45). The left hemisphere appears to perceive details, to analyze and to sequence, to think in propositional, convergent ways. The right hemisphere appears to process stimuli as a gestalt, and to process visual materials, as well as musical tones,more effectively. The right side of the brain

seems to act as a synthesist, to use intuition and leaps of insight rather than using the step-by-step logic of the left hemisphere. The right hemisphere appears to be more subjective, relational and time free than the left (Gazzaniga, 1967, Kimura, 1973, Krashen, 1977, Bogen, 1977, and Murray, 1978),and seems to think in appositional and divergent ways (Kneller, 29-40).

In short, the left hemisphere seems to perceive and process information in parts, while the right hemisphere perceives and processes information in wholes.

Recently, data from brain research has indicated less specialization for both hemispheres than was originally the case. However, the work of Dr. George Ojemann, neurosurgeon at the University of Washington appears to indicate that certain stimuli, specifically language and mathematical processes, may be handled with a great degree of specificity. Dr. Ojemann probed the brains of his patients with electrodes as they read aloud. Depending "on what he touched, (they) found themselves unable to speak the noun, the preposition or another part of speech" (Begley, et al., 47). He also found that bilingual patients appeared to store the same words in different languages in different places. The brain appears to have more than one method of organizing language, as well as storing the words in various places. Some patients have "sites for naming objects in their perietal lobes that ordinarily receive sensations of touch and spatial information," while others have "these naming

sites in the temporal lobes, amid regions devoted to hearing and memory" (Begley, et al., 47). It appears that the brain may have two ways of processing all stimuli, even language, with the location of storage in the brain indicating the perceptual bias of the individual. Further work by Dr. Ojemann should be watched carefully by educators, especially the leaders in the language arts areas.

Although it is yet too soon for the latest data from neurological research to be applied directly to pedagogical questions, research data from medicine and psychology in the 1960's and 1970's have been used to investigate many facets of the teaching/learning process.

Questions of general educational significance have been probed in a broad range of topics from those investigating the physical positions of students in the classroom and the possible effects of those locations on language proficiency (Bakker, et al., 1977), to inquiries into the possibility that Black-White differences in IQ test scores may be related to a White, middle class sensory bias toward left hemisphere verbal, sequential processing strategies that are less a part of the Black experience (Reynolds, et al., 1981).

That a specific bias can be ascertained by testing, and that training can change the direction of the bias or create integrated thinkers, was the subject of one of the many studies of perceptual bias done by Torrance (Torrance and Reynolds, 1980).

They suggest that an "individual's preferred style of learning and thinking might be modified over a relatively brief time period. . . and that the general direction of the change can be controlled." These data may have important implications for educators, if their results are supported by further testing.

Two studies, one with children who wrote Hebrew (Shimrat, 1973), and with adults who wrote Chinese (Biederman and Tsao 1979), imply that the left sensory bias that appears to be the norm in Western society may be the result of our left-to-right system of written language. Further such studies may offer some indication of a hemispheric bias being inherent or learned. At this time, the experts are unsure (Fox, 9).

The use of Galen's Word Shape Sorting Test as a means of determining hemispheric bias in the processing strategies of students has been investigated by Karl, Van Decar and Weingartner (1980), using EEG studies of students' emotional reaction to visual violence in a film, and the results correlated. Their findings appear to further validate the test.

Another study in education based on the early brain research that may have application across subject areas was that of Rice and Languis (1979), in which it was discovered that students faced with incongruent visual and verbal stimuli tended to believe the nonverbal information, in preference to the verbal message.

In the subject area of reading a plethora of studies have grown out of the research into hemisphericity and lateralization. Visual processing of the printed word was investigated by Umilta,

Sava and Salmaso (1980) using dissimilar typefaces to study processing strategies of students. They found that the type style may affect the processing strategy chosen by readers. The data of Gordon and Carmon (1976) tend to support this hypothesis. Their conclusions were that, in processing new symbols or words, subjects tend to recognize new visual materials first according to shape, using a right hemisphere strategy, but, as the materials became more familiar, they processed them with left hemisphere strategies.

Yvonne L. Turner (1978), used the SOI Learning Abilities Test of divergent figural production and divergent semantics production, and concluded that students who scored high on the SOI test were not necessarily high or average when assessed by the Stanford Reading Comprehension test, that those subjects with high scores on divergent figural units scored significantly better on the divergent semantics test than low scorers, but that the relationship was not reversable, and that subjects scoring high on divergent testing made more syntactical errors on the Reading Miscue Analysis than semantic errors. She writes that she believes that the right hemisphere processes the prose aspects of written material, while the left hemisphere analyzes phonemes and syntax. Her data would also appear to indicate that subjects who had well developed divergent thinking skills made more syntatic errors, and lower scores on the reading comprehension test, both of which would indicate

a possible right hemisphere perceptual strategy in approaching written material.

John Kershner studied disabled readers, good readers and gifted children in search for a valid model for the teaching of reading, using tachistoscopic simultaneous bilateral viewing of four letter words matched for similar visual configuration (1977). Using intelligence test scores as a covariate, he found that poor readers produced higher left visual field/right hemisphere scores than did the good readers. He concluded that "reading impariment is a text-specific problem, and is not derived from a general language disturbance. . . (which) may result (from) a perceptual coding strategy that is inappropriate to the processing demands made by comprehending text, and may be inefficient for the achievement of academic success via orthodox reading instruction. . ." (66). In other words, Kershner seems to believe that poor readers are not using the same perceptual strategies to decode the material that good readers use, because poor readers have a bias toward the opposite processing mode, and that traditional teaching practices will only help such readers to fail.

Symmes and Rapoport (1972) found that poor readers who were tested as being within norms for perception and intelligence made above average scores on visualization tests, a right hemisphere function. Levin (1973) used the Iowa Reading Test to identify a group of readers equivalent to the Symmes and Rapoport group, and found that one group of students

had above average visualization skills.. He identified another group who appeared to have decoding skills, but lacked organizational skills in reading.When the latter group was taught simple visualization skills, the scores of the group on comprehension were raised by 40%.

From these studies, it appears that readers who process written material using a predominantly left hemisphere strategy of sequencing, without integrating the right hemisphere visualization strategies, may be able to read, but not comprehend. Those readers who appear to have good visualization skills, a right hemisphere strategy, but lack the sequencing skills of the left, have great difficulty developing overall reading skills. Evidently, the right hemisphere skills can be taught to those who already possess the skills of the left hemisphere, and from other studies, it seems that the strengths of the readers who have a right hemisphere bias can be used to approach the written material using visual strategies rather than the traditional ones to allow those readers to develop the necessary left hemisphere sequencing skills. As Patricia L. Fox wrote in her article in THE READING TEACHER (33, 1, 7-14) in October, 1979, "Good readers seem to integrate the verbal (left brain-sequencing?) and the visual (right brain?) aspects of reading unconsciously." (11).

In the same article, Fox explains that Pascual-Leone and Smith (1969) "found that to learn a new word, the learner must already know the concept for the word. . . For this, children

must experience both positive and negative instances of the word, either directly or vicariously. . . (and that) the most efficient means of giving children these experiences in the classroom is with pictures" (11).

Another study indicates that the most valuable pictures to readers are those that the readers produce themselves. Bull and Wittrock (1973) tested three groups of students on vocabulary items after one group copied the definitions, another read the definitions, and a third group traced pictures that showed the definitions. The test scores on recall were superior for the group that had drawn the pictures. Yarmey and Bowen (1972) found that both normal and retarded students made similar scores on comprehension with the simple exercise of visualizing the material added to the learning exercise. It appears that the pictures need not be transcribed to paper, merely created inside the head to be advantagous to readers.

In her 1979 article, Fox hypothesizes that exercises in visualizing may be of value in tapping the right hemisphere strategies already applied by students with strong right laterality, and may enhance the reading skills of those students whose perceptual bias is strongly toward the left hemisphere's processing strategies.

In the same article, Fox relates the bi-hemispherical processing strategies to the chimera study carried out by Sperry with the commissurotomy patients. Those data indicated

that split-brained subjects created or visualized the missing portion of a picture when a 'chimera' consisting of half a rose and half a human face was presented to each hemisphere separately. Both hemispheres indicated in tests that the entire picture of each visual was presented. Each hemisphere generated a complete picture from a part. Fox relates that Frank Smith calls this "generative processing," and she hypothesizes that humans can complete sentences and pictures according to expectencies. . . (that) readers anticipate meaning based on prior knowledge of semantics, syntax, and subject matter. . . (12). She also states that "with increasing skill readers depend less on decoding skills and more on generative skills" (12).

Fox also writes that "readers who use only the right side of the brain are unable to respond traditionally to the teachers' comprehension questions. Students who rely on the left hemisphere will remain reading students and never become readers. . . " (12). Marilyn Winzenc writes, in a paper presented to the California Reading Association of the IRA in 1977, that "the challenge for the teacher of reading is to draw on both modes of knowing to enhance comprehension. . . to ignore the functions of the left hemisphere is to teach only half the child. . . " (1977, 113).

Professor Michael Gazzaniga in his chapter, "Review of the Split Brain," in THE HUMAN BRAIN (Prentice Hall, 1977, Wittrock, ed.), writes that "an intriguing possibility of

of research findings is the possibility that. . . superiority in the verbal area might not necessarily mean superiority in the visual-spatial area---while the reverse may also hold true. If this proves correct, it may well follow that a (student) might be able to solve a problem using verbal symbols with greater ease than using visual-spatial ones, while another. . . might be better off solving the same problem using visual spatial relations" (94). Could Gazzaniga's theory be applied to the teaching of reading?

Professor Robert Nebes of Duke University, writes that "if there is any truth in the assertion that our culture stresses left-hemispheric skills, this especially true of the school systems. . . If the right hemisphere does indeed process data in a manner different from the left, we may be shortchanging ourselves when we educate only left-sided talents in basic schooling. . . Many problems can be solved either by analysis or synthesis; but if people are taught to habitually examine only one approach, their ability to choose the most effective answer is diminished. . . (Nebes, 105).

As Emerson wrote, "One must be an inventor to read well. . . ," and it may be true that one must be an inventor to think well also. Winzenc quotes Ulrich Neisser (COGNITIVE PSYCHOLOGY, Appleton-Century-Crofts, 1967, 136) who writes, ". . . instruction in reading comprehension must be viewed as instruction in thinking. . . reading is externally guided thinking, . . .

perhaps we should not be surprised that it so poorly understood; we may not understand it until we understand thought itself. . ."

It appears, then, that given the basic research data, the findings of educational researchers, and the theories of those in both brain research and education, the challenge to educators, and especially to the teachers of a skill carrying the cultural weight of reading, is to teach the whole child, to approach each hemisphere's processing strengths, and to provide exercises that will allow for the integration of perceptual strategies in reading, and to produce holistic thinkers. Our reading/listening and talking/writing emphasis in all the language arts may be not only handicapping the proportion of students whose preceptual strategies are not tapped by current teaching techniques and materials, but may also be allowing the development of a culture made up of people who will be able to use only half of their potential. The implications of teaching the skills involved in reading reach far beyond the act of reading itself.

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